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THE DISPOSAL OF INDUSTRIAL WASTES

by George E. Barnes

SANITARY ENGINEERING DIVISION

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THE DISPOSAL OF INDUSTRIAL WASTES

George E. Barnes*

Sanitary engineering, formerly concerned primarily with pollution problems that arise from the mere occupancy of municipal areas by population groups, now is very involved with the matter of industrial wastes. Whether from quality or quantity, the importance of industrial wastes now equals or possibly exceeds that of sanitary sewage, in sanitary engineering. Thus today, our concept of sanitary engineering has broken away from the more restricted thinking of the past, and inevitably, there have been marked changes in practice. As one result of this, we have the industrial engineers, who are not likely to be specialists in sanitary engineering, required to work as never before with those who are specialists in the field; and they find that they have to orient themselves in the subject to a certain extent, in order that all common interests in a given locality may be served suitably and economically, where waste disposal is a problem. With this situation as something of a foundation for the nature of the discourse which follows, then, I propose to offer to this group, in a very simple and direct way, some of the more interesting and pertinent aspects of this specialized branch of sanitary engineering. I shall touch upon (1) the magnitude of the problem, (2) what is signified by stream pollution, (3) the general characteristics and behavior of domestic sewage and the usual methods for treatment of it, (4) the meaning of the term "population equivalent", (5) the more general kinds of industrials wastes and their different contaminating effects, (6) industrial waste treatment methods in general, (7) some specific case histories of situations and remedial measures, and finally, (8) certain trends which are developing, and policies which are being formulated, between industry and the public authorities. Obviously, such a coverage can only be made in summary fashion, and there is some risk of oversimplifying certain aspects of the subject in the interest of brevity, and of omitting many details that would warrant, under other circumstances, much more ample treatment.

Magnitude of the Problem

In the United States, the second world war saw the birth or sudden expansion of industry and especially of new industries, such as synthetic rubber and plastics as random examples. Waterborne wastes were correspondingly large in volume and diverse in character. Sanitary engineers became acutely aware that the situation was posing a disposal problem about equal in magnitude to that of the disposal of the ordinary domestic wastes of the entire population of the country, and a problem perhaps even more complex.

The latest report of the National Resources Committee shows about half the population of the country serviced with sewer systems. The total flow in

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all the sewers was some 5.75 billions of gallons daily, roughly half receiving some treatment and half being discharged raw into the streams. This means that the country as a whole is pretty well sewered, for communities are pretty well accounted for; but it also means a great deficiency in treatment works even for domestic sewage, let alone the more newly superimposed load of wastes from industry, equivalent to the domestic pollution of an additional population of 100,000,000 persons.

In Cleveland, it may be noted in passing, the population equivalent of industrial wastes going into the Cuyahoga River, is about equal to the actual population of the City.

Relative to stream pollution, there has been a long jurisdictional dispute and legislative battle between the federal government and the states, now pretty well resolved into state control and federal advisement, plus many local actions by municipalities which have passed ordinances relative to trade wastes. The principle of sewer rentals is widely accepted now, and where sewer rental is charged it is easy to take the next step; that is, to make incremental charges for special wastes.

The Meaning of Stream Pollution

Any discussion of waste disposal must take into account the meaning of stream pollution and the significance of sewage treatment; that is to say, the biochemical aspects of it, since the crux of the matter is in biochemical balance.

A watercourse must be viewed as a living organism, replete with varied aquatic life in a liquid atmosphere of normal purity. It may be used to carry away the wastes of a community only if these do not degrade it to the point where nuisance or danger results. One may not interfere with the proper utilization of the stream by others, without violating riparian rights under the common law.

Extreme cases of river fouling have been numerous. Manhattan was at one time pointedly called an island surrounded by sewage. At one time the harbor depth at New Haven, Conn., had been diminished 11.0 ft. by sewage sludge deposits. Tastes and odors from waste styrene, butadiene, and from other chemical plants around Charleston, W. Va., persisted in the water supplies derived from the Kanawha and Ohio Rivers all the way to Cincinnati. Chromium in the Little Miami River killed so many fish that the offending industry was required to furnish 400,000 new ones for restocking, plus money damage. Many instances could be cited, but one need not dwell on the extreme ones to point up the pollution loading. It is not necessary to poison a stream, or to fill it up, to cause damage.

The most common form of damage comes from depletion of the normal oxygen content of the stream, by substances such as domestic sewage, or the iron-bearing spent pickling liquors from the steel mills, for example, whose biochemical-oxygen demand is relatively high in strong doses. At normal temperatures, natural waters hold but about 0.8 percent of dissolved oxygen by volume, or say 9 to 12 parts per million by weight, which is only about 1/30th that in the atmosphere. The oxygen requirement for aquatic life is replenished by reabsorption from the air, but the balance is sensitive owing to the small amount of available oxygen present, and if abnormal demands are made upon it it may fall to less than 3.5 parts per million, which is about the critical limit for fish life.

In short, the strength of a sewage, or a trade waste, is most frequently to be measured by the quantities of suspended matter it carries and which may

sludge out, and by its biochemical oxygen demand. These are primary measures of polluting effect.

Basic Character and Behavior of Sewage

Sewage normally is purer than Ivory Soap, that is to say, it normally carries less than 1/10th of one percent of solids in solution and in suspension, or say less than 1,000 ppm. including all the garbage, trash, fecal matter, urine, street washings and all that variety of unwanted material which is flushed into the drains. It is seeded with and offers abundant food supply in the form of organic material for a myriad of bacteria, and largely through their agency a number of changes take place from the point of origin on down the line. Until the oxygen in the water supply is used up, the starches, fats, proteins, and carbohydrates are changed over with the production of inoffensive and stable compounds such as water, CO_2, and nitrates and sulfates. When however, the free oxygen is exhausted, certain bacteria succumb and only those capable of extracting oxygen from compounds can survive, and the result of their life processes are mineral and organic compounds and foul-smelling gases such as H_2S, ammonia, mercaptans, and fetid and putrid vapors. These are so-called septic conditions and may arise within a few hours. If sewage enters a stream, comparable cycles of biochemical changes result, modified of course by the new environment.

Object and Method in Sewage Treatment

Clearly the object of sewage treatment, in simplest terms, is to capture particularly the organic solids and to furnish by mechanical and controlled means the oxygen required in pounds to satisfy the biochemical oxygen demand, hereinafter called simply the BOD. Depending upon the opportunity for dilution in watercourses, treatment may properly range all the way from simple screening, or none at all, to the production of drinking water.

However, in practically all plants, unless bathing beaches are to be protected by chlorination of the effluent, no attention is given to the removal of bacteria from the effluent. These may be myriad in number, but they starve to death anyhow shortly after their food supply is left behind.

The matter of conditioning and disposal of the scum, grit, screenings, and sludges left behind after treatment is another story. Upwards of 50 percent of the organic matter in the sludge may be gasified or destroyed in digestion tanks, Cleveland having the largest single installation in the world at the Southerly Plant for this purpose. The rest is a matter of dewatering and disposal of the remaining inert solids to fill, or total destruction in incinerators.

The degree of treatment, whether with reference to the sewage itself or to the by-products, depends on local necessity. The methods adopted must be chosen with a view to economy, of course.

There are about 6,000 sewage treatment plants around the country of one type or another. Some cost over a million per year to operate; others are small town jobs. Some use chemicals to enhance settling, but practically all of them depend in the large sense on natural, biochemical processes, being virtually installations to accelerate and control the changes that would occur in nature anyhow, but without nuisance or health hazard.

In Figure 1, for example, there is shown a flow sheet of a typical sewage treatment plant for domestic sewage, with all the elements necessary for the several phases of treatment, including those for the treatment of the by-products. The letters "F", "B", and "T" indicate the different points at which

the treatment is basically physical, biochemical, or thermal.

The significance of the foregoing statements is of utmost importance in connection with considerations on industrial waste disposal. Whether industrial wastes go to a stream or to a municipal sewage treatment plant, they are going to upset conditions if they are excessively acid, excessively alkaline, toxic, or in any way inimical to biochemical life cycles, whether in the stream or in the sewage treatment plant.

The "Population Equivalent"

The so-called population equivalent is a convenient unit for measuring the pollution effect of a waterborne waste of any kind. The standard is a normal domestic sewage of arbitrary characteristics. If we divide the total average flow of sewage from communities by the total population, we get around 100 gallons per capita per day. The sewage will have somewhere around 240 ppm of suspended solids, and 200 ppm of BOD, or, expressed directly in weight units, 0.200 lbs. of suspended solids and 0.167 lbs. of BOD, per capita per day.

These figures are the units for comparison. Any waste contributing the same would be said to have a population equivalent of one (1).

It should be noted in passing that there is no reason to expect that the population equivalent based on suspended solids should equal that based on B. O. D., unless, of course, it so happens for a particular waste that the two are in the ratio of 240/200, as for the so-called normal domestic sewage.

By ratio and proportion then, the population equivalent of any waste can be quickly computed. In Figure 2 there is shown such a computation for a brewery, having wastes organic in character. The unit of production is one barrel; and in making one barrel of beer, 300 gallons of industrial waste go to the sewer. Therefore, if the waste had the same suspended solids and BOD as domestic sewage, based on volume alone, a production unit would have a population equivalent of three (3). But it has a suspended solids content of 650 ppm, or 2.7 times that of sewage; and it has a BOD of 1200 ppm, or 6.0 times that of sewage. Therefore the population equivalent based on suspended solids is 3 times 2.7 or 8.1; and based on BOD it is 3 x 6 or 18 persons, per unit of production. Since the total production is 500 bbls. daily, the population equivalent of the industrial installation is 500 x 8.1 = 4,050 persons, or 500 x 18 = 9,000 persons, depending on the base used for comparison.

The population equivalent per unit of production has been computed for about 30 types of industry, based on so called typical operational norms, such as in canning, paper manufacture, textiles, rayon, dairy, meat packing, woolen goods, distilling, and other industries.

Obviously certain wastes have no population equivalent, since their contaminating potencial has little relation either to suspended solids content or BOD. Nevertheless the yardstick has broad application.

Other Types of Industrial Wastes

Waterborne wastes from industry are of such diverse character they do not lend themselves readily to classification. However, among those whose pollution effect is not properly or totally measured by population equivalent, are the following:

(a) Acids: Acids (such as pickling liquors) may coagulate or precipitate other substances, causing high turbidity or sludge deposits. Excessive acid-

ity inhibits biological processes, and solutions of pH 6.0 or lower may damage structures and equipment by corrosion.

(b) Alkalies: Excessive alkalinity and causticity (as from textile works, laundries, tanneries, and chemical works) are antiseptic and inhibitive to sewage treatment and stream purification. Fish life is adversely affected and may succumb.

(c) Oils and Greases: Floating oil and scum are unsightly and harmful to aquatic life and waterfowl. A little bit goes a long way, as 200 gal of oil may form sleek over a square mile of water surface. Oil and grease, either free or emulsified, are difficult to oxidize, and interfere with normal oxidation of other matters.

(d) Phenols: Phenolic substances from coke ovens and chemical industries have long been a problem, owing to their high B.O.D., but more particularly to their taste-forming properties in water supplies. Chlorination of water supplies bearing phenols in even minute quantities (even one part per billion) may form chlorophenols which are unpalatable.

(e) Styrene: Styrene may be mentioned as another example, of more recent significance, of a taste former in water supplies. It is one of the two primary raw materials used in making the commonest form of synthetic rubber. Unless tremendously diluted, it imparts a vinegary or winey sweetish odor and taste to water supplies, which is expensive to remove by any known method.

(f) Tanning: Tannery effluents are an example of a class of organic wastes which not only deoxygenate streams, but diffuse inky solutions which impart highly persistent and offensive color.

(g) Metals: Heavy metals such as copper and chromium, where not recoverable from plating wastes or other sources, are toxic materials and cumulative poisons. They have been known to diminish or stop nitrification and digestion stages of sewage treatment and to kill fish.

(h) Cyanides: Cyanides in very low concentrations are extremely poisonous and even dangerous; they interfere with or stop biochemical processes and kill fish.

(i) Brines: Brine is the raw material for the production of a wide variety of chemicals; it is commonly used as a dispersing agent; it is a common by-product of oil production. It is harmful to agriculture, to livestock, to water supplies and to normal fresh-water aquatic life.

(j) Detergents: Detergents, or "soap substitutes" are dispersing agents that inhibit the normal functions of sewage treatment. They are of many types, generally high in BOD, inhibiting sedimentation, causing foaming. One small plant in Indiana was buried under foam eight feet thick. At other large plants, in New York, Chicago, and Cleveland Easterly, there has been foam nuisance, not serious as yet.

(k) Radioactive Wastes: Very briefly, radioactive substances can be extracted by the same processes used for the substances when non-reactive. However, the extracted materials, if high in radioactivity, cannot be disposed of by ordinary means. The radioactivity cannot in any case be destroyed. Such materials must be stored, or buried for permanent isolation.

Treatment Methods

Where such wastes require treatment, certain general approaches suggest themselves, so that the wastes may be separated, reduced, neutralized, or diluted out.

One would have to review the whole field of chemistry and bacteriology to make a mere outline of general methods for accomplishing these ends, such as the neutralizing of acids and alkalies, emulsion-breaking and flotation methods, biochemical destruction, solvent extraction, and others of like character.

One generally helpful suggestion is to study in detail the possibility of timing their release. Providing an accumulation tank to hold a day's flow from which regulated, uniform discharge results, instead of batch or concentrated discharge during the work shift, may be all that is needed.

It is important to point out certain sources here. On an industry-wide basis, some groups of industries have pooled experience, underwritten research, and published manuals on approved disposal practices. We should mention in this connection the American Petroleum Institute Committee on Disposal of Refinery Wastes, the Mellon Institute Reports to the American Iron and Steel Institute on treatment of pickling liquors, the research program of the paper industry in the National Council for Stream Improvement, and the work of standing committees in individual group industries, such as General Motors, for example.

On a locality basis, the Chicago Sanitary District works continuously with local industries, in the savings of materials, the recovery of by-products, and suitable waste treatment.

The "Final Report to the Ohio River Committee, Ohio River Pollution Survey" of the U.S. Public Health Service, previously cited, includes a supplement of industrial Waste Guides, on waste disposal in brewery, cannery, coal washery, coke, cotton, distillery, meat, milk, oil, paper, and tannery industries. This series of guides, under one cover, gives the raw materials, flow sheet, and end products of each industry, the nature and strength of its wastes, and suggestions on disposal or treatment.

Of course such general material can only suggest a basic approach. A chemical equation is not a flow sheet; and a flow sheet is not a process installation. For a particular situation, whatever the industry, one must come down to local and to environmental factors, and more particularly the evaluation of the basic nature and volume of the flows, as well as their departure from the average, and considerations for the future.

Industrial wastes are never simple solutions nor simple suspensions. They are whatever goes down the drain in a given plant. Where wastes are combined, it may be necessary to separate them at the source, and to recombine them perhaps to get the best opportunity for treatment. There may be substances present which inhibit the basic treatment.

But it is not my purpose to point out obvious engineering problems to engineers. I wish rather to stress the necessity of coming down to cases, rather than taking the risk of following out preconceived notions, in devising treatment methods for a particular waste. For success in the ultimate installation, a considerable program of laboratory experimentation preceding design is almost a must, and certainly good insurance and economy in the long run.

Some Illustrative Case Histories on Installations

To be more specific yet, I wish to describe very briefly a few different installations, stating the problem in a few works, and also the remedy. In these examples, the most effective process for adoption was worked out by experimentation in the Sanitary Engineering Laboratory at Case, after many alternates were tried and evaluated.

Figure 3 - Oil Disposal: An industry making machine parts used a large quantity of cutting oils which fouled a nearby stream used for recreation purposes in a metropolitan park. On complaint of the public authorities, an oil-separation method was devised. This consisted of catching the day's spent supply, breaking the emulsion with calcium chloride in tanks with agitators, skimming the supernatant, and burning it in an incinerator. The slide shows a plan view and a sectional view of the equipment. Each of the two containers acts as a receiver on alternate days. At the end of the day, the emulsion breaker is mixed with the waste and violently agitated for a short period; then allowed to remain quiescent for separation. The scum is floated off by admitting water to the bottom, and carried away in gutters to a receiver, in which it is carted to the incinerator to be burned. The clarified liquor goes to the sewer.

Figure 4 - Acid Neutralization: An industry serviced by city sewers discharged several tons of spent sulfuric acid into the system by permission of the authorities, but damage resulted. An automatic neutralizing plant was set up by the industry. The slide shows pebble lime coming in by railroad and transferred by vacuum unloader to overhead storage. A dry chemical feeder and slaker furnishes milk of lime to a surge tank, discharging through a butterfly valve to be mixed with the raw acid wastes in a baffled neutralizing chamber. If the pH of the effluent should tend to drop below 7.0, or whatever figure is set, electrodes immersed in the flow actuate the butterfly valve on the surge tank to admit more milk of lime. When the surge tank level is drawn down, float valves start the feeder to replenish the supply. The flow is continuous over 24 hours and the plant writes its own record. Owing to the low concentration of the sulfates following neutralization, no provision is made for handling sludge. There is none.

Figure 5 - Steel Mill Pickling Liquors: There are eight somewhat different but accepted methods for neutralizing mill pickling liquors in which the removal of iron salts is a necessary element. Here is a continuous flow plant devised for a mill pickling say 6,000 tons daily with a waste flow of 20,000 gallons. A surge tank collects the raw liquor and permits uniform pumping through the plant. Neutralization and precipitation is accomplished by feeding milk of lime, with flash mixing, conditioning of the mix in flocculators, and clarification in settling compartments. The clear liquor goes to the sewer; the sludge to lagoons.

Figure 6 - Cyanides Removal: A state barred certain cyanide bearing wastes from a sizable stream. The industry treated its cyanide

wastes by three different methods in succession, i.e., iron treatment to form insoluable ferri-ferro-cyanide complexes, then by the application of sodium-acid-sulfite, and finally, as in the installation shown, by chlorination. The raw wastes enter ar accumulation tank, are transferred to treatment tanks, analysed, and the proper dosage of chlorine figured for the batch. Chlorinators of orthodox type furnish the chlorine solution to be mixed with agitadors and the cyanides are destroyed. There is no sludge, although blowdown valves provide for removal of sediment. Lest a small amount of tear gas escape from the surface and to the neighborhood, hoods collect the atmosphere over the tank, and fans pass it through an absorption tower to be dissolved and to go down the sewer.

Figure 7 - Removal of Chromium, Copper, and other Heavy Metals: In connection with the preceding installation, acid pickling liquors bearing heavy concentrations of chromium, copper, and some nickel, zinc, and aluminum, had to be treated. The metal-bearing acid wastes contain both hexavalent and trivalent chromium and are treated with ferrous sulfate to reduce the hexavalent to the trivalent form. The trivalent chromium, along with the salts of copper and nickel, is readily precipitated with lime. Chemical solutions of a known concentration are made up with dry feeders, as shown. The raw acid wastes originating in one day are accumlated, and are pumped the following day to the treatment tanks. After analysis of the wastes, the chemical solutions are added in the requisite quantities, and the mixture is agitated vigorously for some time, after which the mix is allowed to settle. The clear supernatant goes to the sewers through a flow-rate controller; the sludge to the sludge well. The sludge is concentrated in a thickener unit before storage in elevated tanks, from which trucks take it to the lagoons outside the city. In this plant, concentrations of metals as high as 20,000 p.p.m. have been reduced to 10 parts and less.

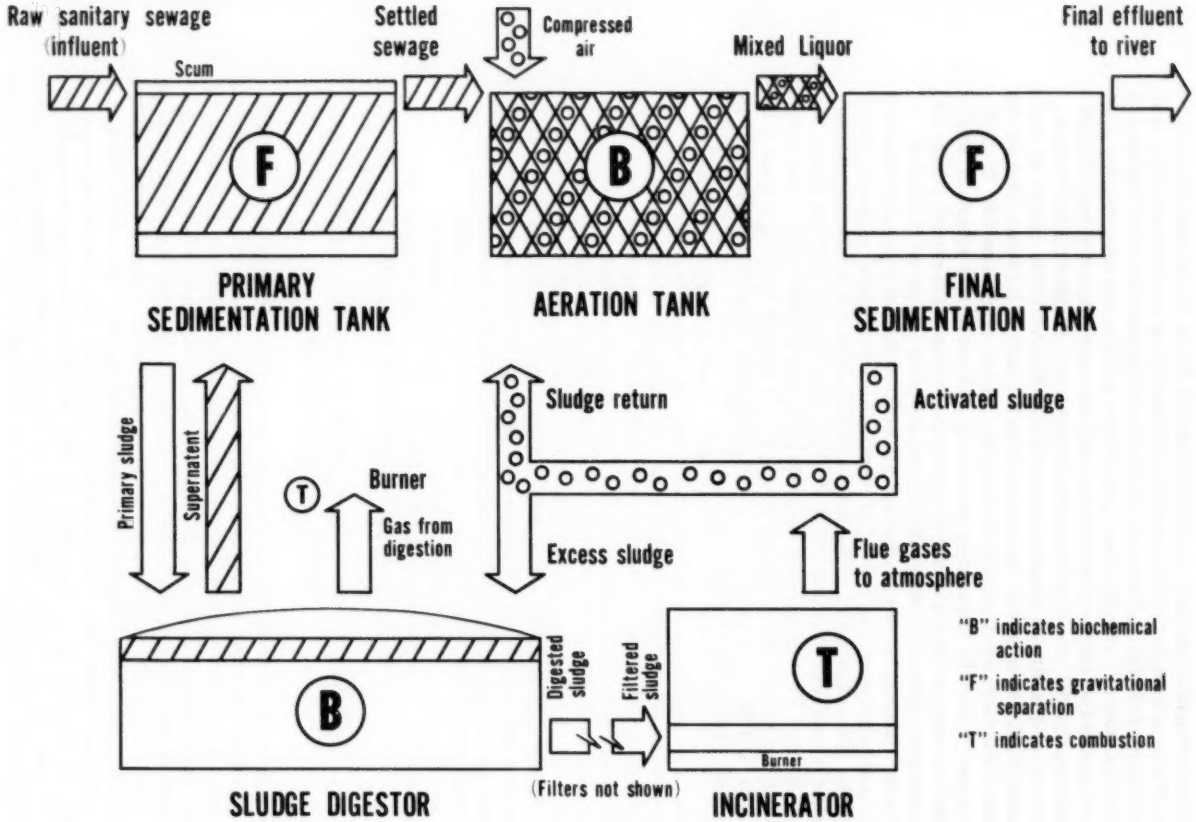
Relations between the Public Authorities and Industry; General Matters of Policy

It would be most pertinent, in closing, to point up certain trends that are developing on policy matters between the public authorities and industry, in connection with trade waste disposal. Two viewpoints, obviously divergent at times, are to be considered. Industry holds in some instances that the municipality could not exist as such without its payroll, and without its purchase of public water supply; and that it is therefore up to the city to take care of its industrial wastes. The public authorities however, may contend that since the sewerage system and treatment works are built with public moneys, their total obligation extends no further than to take care of the ordinary by-products of community living, and that to spend public money to take care of the wastes of special industries is not a fair burden for the public authorities to assume. A compromise has to be worked out, - something equitable for all.

Many municipalities (Akron, Buffalo, the Chicago Sanitary District), and others, already have local ordinances or rulings pertaining to the matter. If all such ordinances are studied for essence, leaving out exact details, a common principle emerges which can be briefly stated as follows:

The municipality will take care of industrial flows, along with domestic flows, if they are equivalent in quantity and quality to domestic sewage, and without special charge. If however, there is an incremental cost incident to handling the wastes, whether from quantity or quality, the municipality may elect to handle the wastes provided the facilities permit, but it will charge the industry for the incremental costs of doing so. Further, if the wastes, whether from quantity or quality, are such that the facilities cannot be made to handle them, the municipality may refuse the industrial flows, and put the burden on the industry direct of treating the wastes at the source. It is at once apparent that the arguments pertaining to a particular situation, are to be resolved only by fair methods of appraising these incremental costs; i.e., what elements enter into the problem, and how they are to be evaluated.

Finally, industry must assume that all such treatment costs are after all a legitimate charge on the cost of production in a particular location. New industries are assuming this squarely, and provision for waste disposal is now almost universally made in the original plant design, and not left to be tacked on later, at even greater inconvenience and greater cost. The proper provision for waste treatment and disposal is a matter of being a good neighbor, also, and the very real value of that intangible thing called good will is also an element in the overall picture.



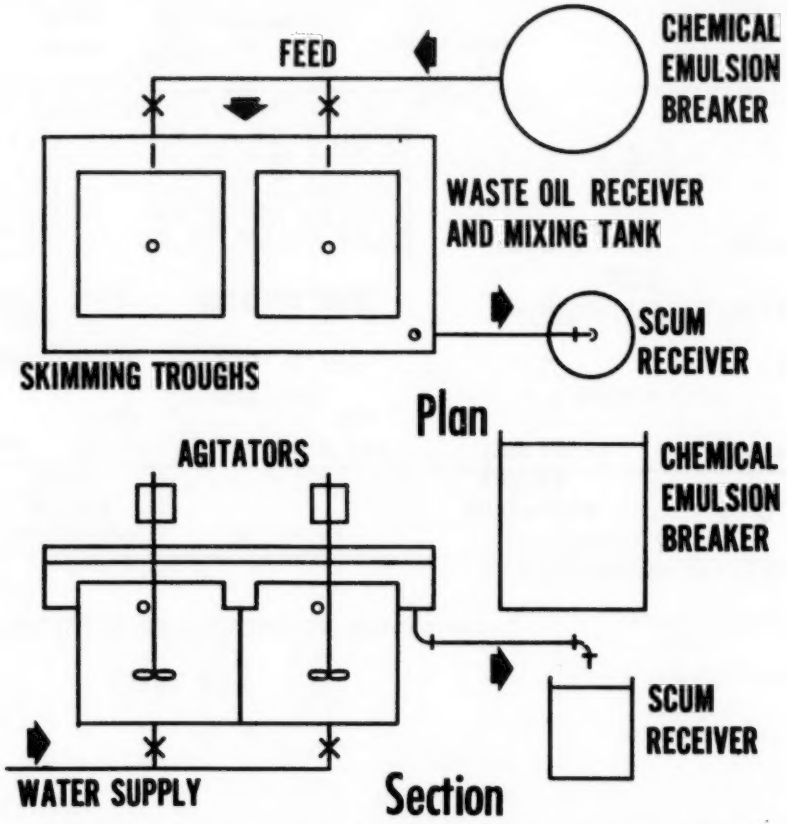
COMPLETE TREATMENT FOR SANITARY SEWAGE AND DISPOSAL OF BYPRODUCTS

Fig. 1

Slide 2.

Sample Estimate of Population Equivalent

Item	Analysis				Population equivalent (based on)	
	Suspended solids		B. O. D.		Suspended solids	B. O. D.
	ppm	lbs per day	ppm	lbs per day	(persons)	(persons)
Domestic sewage (100 gal per capita)	240	0.200	200	0.167	1	1
Brewery wastes 300 gal per bbl	650	1.62	1200	3.000	8	18
Brewery producing 500 bbl per day	..	..	..	..	4000	9000

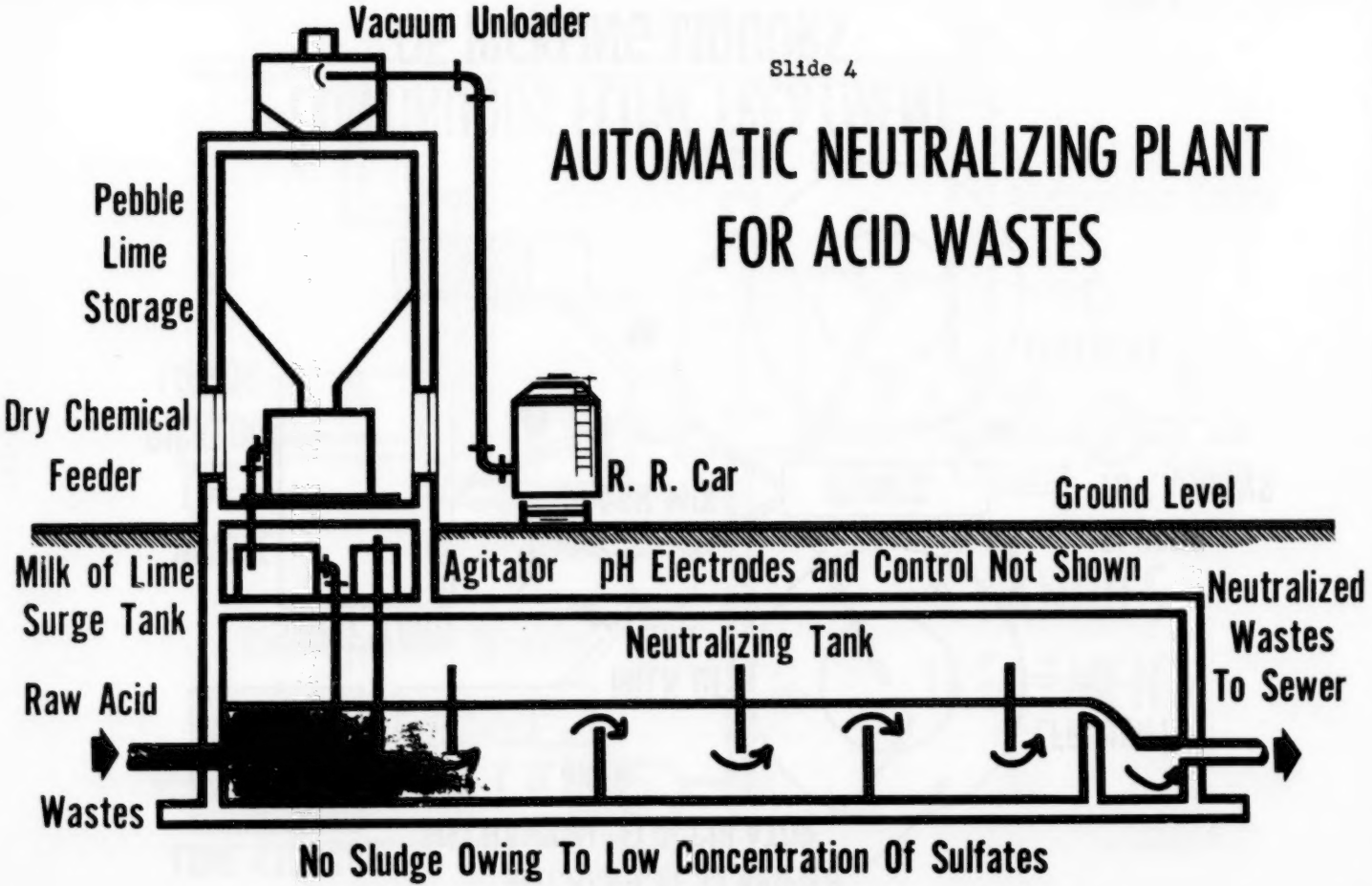


OIL SEPARATING EQUIPMENT FOR SOLUBLE OILS

Slide 3

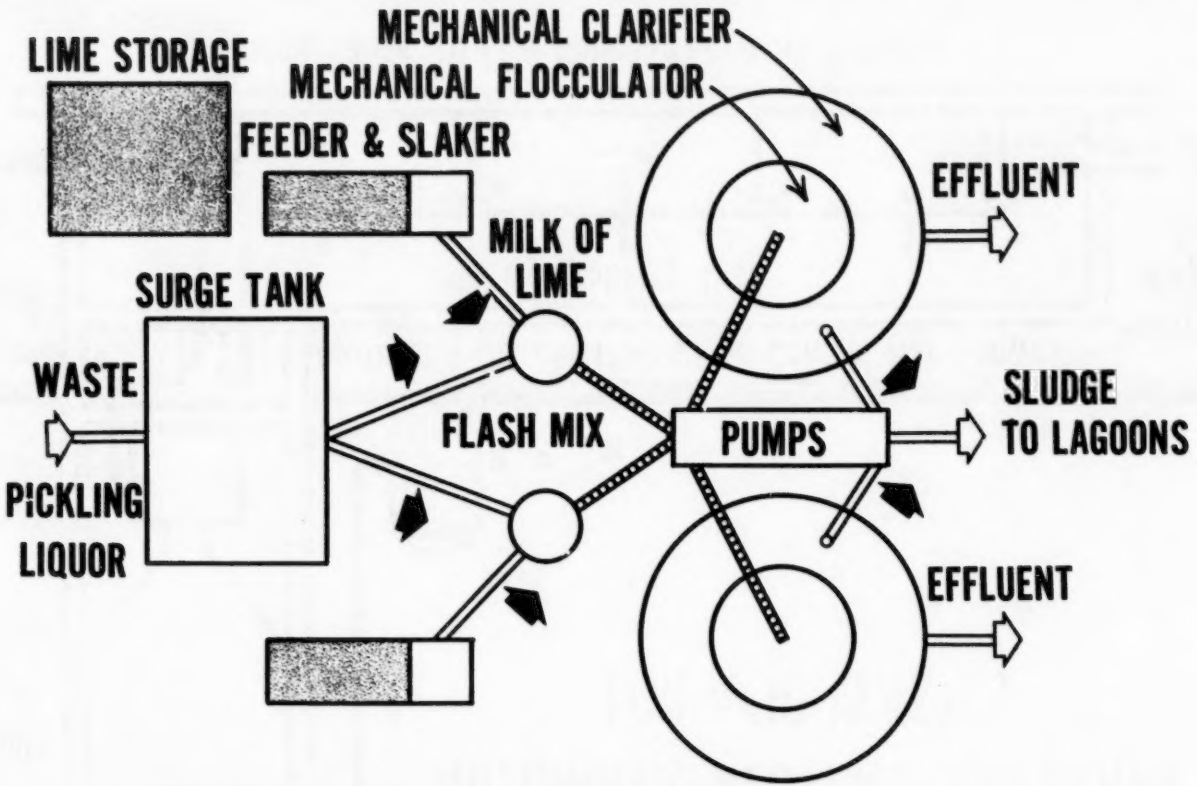
Slide 4

AUTOMATIC NEUTRALIZING PLANT FOR ACID WASTES



No Sludge Owing To Low Concentration Of Sulfates

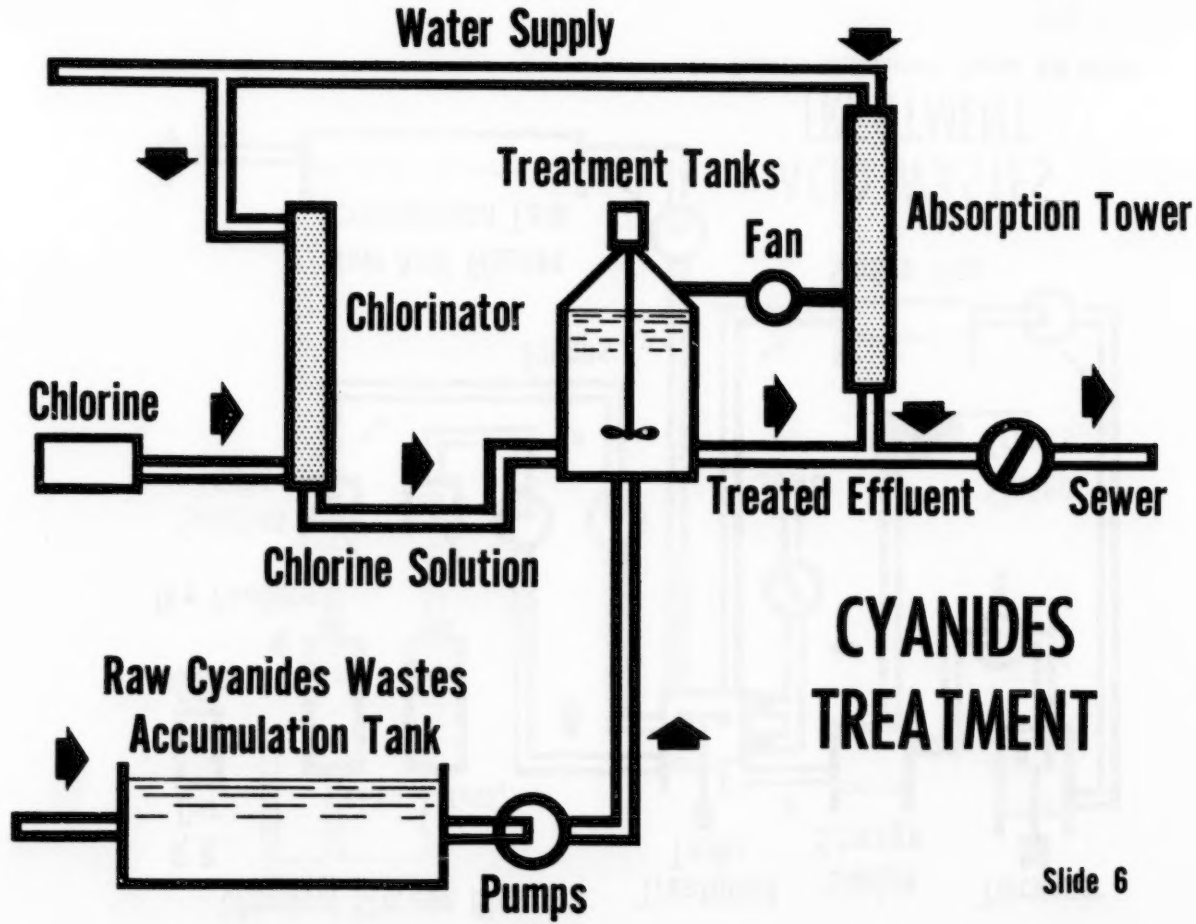
247-13

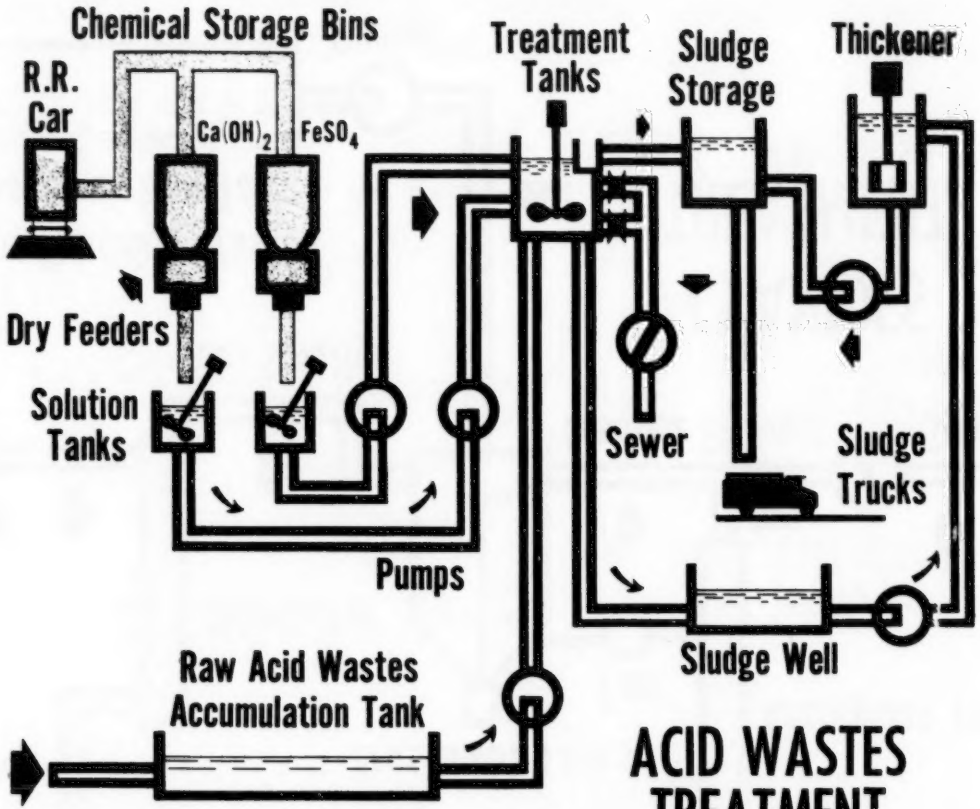


CONTINUOUS FLOW TREATMENT OF PICKLING LIQUORS

247-14

Slide 5


Water Supply
Treatment Tanks
Absorption Tower
Fan
Chlorinator
Chlorine
Treated Effluent
Sewer
Chlorine Solution
CYANIDES
TREATMENT
Raw Cyanides Wastes
Accumulation Tank
Pumps
Slide 6



ACID WASTES TREATMENT

For Removal Of Chromium, Copper And Nickel

Slide 7

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